Ozarks Environmental and Water Resources Institute (OEWRI)

Final Report

Geomorphic Assessment of South Creek between National and Campbell Avenue, Springfield, Missouri

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PROJECT SCOPE

Olsson Associates (OA) contracted the Ozarks Environmental and Water Resources Institute (OEWRI) at Missouri State University to complete a geomorphic study of the main stem of South Creek in Springfield, Missouri. The study involves the collection and interpretation of channel topography (channel profile and section surveys) and boundary conditions (bed and bank substrate) to support the planning and design phases for a channel improvement and restoration project along South Creek between Campbell Avenue and Kansas Expressway. This report will describe the data collected and interpret the data in the form of recommendations regarding the geomorphological context of the stream.

The purpose of the geomorphic study is to evaluate existing channel upstream of Campbell Avenue to identify channel properties that can be implemented into a channel design that provides long-term stability of the channel between Kansas Expressway and Campbell Avenue.

The geomorphic field and analytical work will consist of:

1. Longitudinal profile survey to determine riffle-pool spacing, residual pool depth, and riffle-riffle slopes.
2. Cross-sections at several typical locations will be surveyed to determine the size of the upstream channel for use in geomorphic-hydraulic analysis.
3. "Pebble counts" of the active channel will be performed to understand the size of the bed material present for transport and the distribution of material over the bed for roughness and sediment transport estimates.
4. Comparison of the channel shape to surveys collected in 2004 to understand how the channel has adjusted over the last 10 years
5. Analysis of 1953, 1975, and 2009 aerial photos of the study reach document the historical channel position, planform patterns, and history of human disturbance.

PHYSICAL SETTING

The South Creek watershed is located in south Springfield and drains 10.8 mi^2 at its confluence with Wilson's Creek (Figure 1). South Creek is a 2nd order tributary of Wilson's Creek located in the Springfield Plateau physiographic subsection of the Ozarks of southwest Missouri in southern Greene County. The stream's flow begins just downstream of National Avenue and flows west to the confluence with Wilson's Creek located near the Southwest Clean Water Plant. The artificial (concrete) stream channel extends upstream of National for an entire length of over 39,000 ft (≈6.4 mi). The underlying geology is Mississippian age limestone in which is formed a karst landscape with numerous sinkholes, losing streams, and springs. Soils in the watershed are typical of uplands in Greene County consisting of cherty limestone residuum parent material with a thin loess cap formed under prairie vegetation (Hughes, 1982).

The project reach is approximately 6,000 ft long located between Campbell Avenue and Kansas Expressway (Figure 2). The stream within the project reach is channelized, relatively straight, trapezoidal, and grass-lined with a narrow concrete trickle channel. The trickle channel widens when it passes under a series of 5 box culverts at Campbell Avenue, a private drive going to the First Home Savings Bank, Grant Avenue, Fort Avenue, and Kansas Expressway. A small dam just downstream of Kansas Expressway backs water upstream under the bridge where it stays ponded year round. The upstream drainage area at Campbell Avenue is 1.8 mi^2 and the upstream drainage area at Kansas Expressway is 3.2 mi^2.

Flow duration analysis shows the stream produces relatively consistent low flow, with not a lot of variability throughout most of the year. OEWRI has had a stream flow gaging station over the last 2+ years at Campbell Avenue collecting continuous stage data every 15 minutes (Figure 3 and 4). There is only a 0.04-0.59 ft^3/s difference between the 10% and 90% flow (Table 1). The 50% flow exceedance discharge is 0.24 ft^3/s and the 10% exceedance flow is 0.59 ft^3/s. The maximum discharge recorded over the last 2+ years is 675 ft^3/s. The stream was dry for about 3% of the year, during a very dry hot summer.

METHODS

Existing Geomorphic Conditions

Two reaches were used for this project to access the existing stream conditions are located upstream of the project reach between Campbell and National Avenue. Upstream Reach A (UR-A) is located between stations 9,000 and 10,000 feet upstream of Jefferson Avenue. Upstream Reach B (UR-B) is located between stations 6,000 and 7,000 downstream of Jefferson Avenue. The channel between Campbell and Jefferson is channelized, relatively straight, trapezoidal, tree-lined riparian corridor with a natural bed of gravel-cobble sized substrate. The upstream drainage area at National Avenue is 0.9 mi^2.

Geomorphic data on the existing channel conditions upstream of Campbell Avenue were collected including a longitudinal profile, channel cross-sections, and pebble counts. The longitudinal profile and channel cross-sections were measured using an auto-level and stadia rod at glide-riffle crest transition zones when present. Pebble counts were collected at each cross-section to describe the variability in grain roughness along the bed and assess sediment mobility. The intermediate diameters of 15-30 bed samples were measured for both riffle/glide areas at each cross-section site where bed sediment was available. In addition, the diameters of the 3 largest mobile clasts were also measured.

Channel dimensions, substrate properties, and bedform are used to analyze flow properties, flood conditions, and sediment mobility. Discharge is calculated at both the low flow channel and the channel-full capacity using the continuity equation. Manning's equation is used to calculate mean velocity of the flow for use in the continuity equation. Manning's equation requires a roughness coefficient "n" value that is estimated in this protocol using a field based method. Mean channel velocity is calculated as follows:

Channel shear stress values (Tc (lbs/ft^2)) were also used to determine the critical bed material diameter (Dc (mm)) using the empirical equations of Leopold et al. (1964) as:

$$Dc = (77.966)\ Tc^{1.042}$$

and Rosgen (2006) as:

$$Dc = (152.02)\ Tc^{0.7355}$$

Historical Aerial Photography

Aerials photography from 1953, 1975 and 2009 were used to identify historical channel changes that could impact restoration designs (Table 2). The 1953 and 1975 aerials were rectified using the 2009 aerial photo obtained from the City of Springfield using standard methods (Hughes et al. 2006, Martin and Pavlowsky 2011). The channel centerline through the study reach was digitized for each year to analyze historic channel position, planform pattern, and meanderbelt width. Historical land use patterns are also examined to better understand the human impacts on stream disturbance and document channel modifications in the past.

Previous Channel Data

Present day upstream reach channel morphology will also be compared to regional urban channel morphology developed for streams in the Springfield area. Springfield urban stream channel regional curves were developed from field-based measurements collected by Horton (2003) and published by Pavlowsky (2004) on the South Dry Sac River in north Springfield. These data were further augmented by unpublished channel survey data collected by Pavlowsky in 2004 at 10 sites on similar size streams in Springfield in the James River Basin. This includes bankfull channel cross-sectional size, bedform spacing, pool depths, and meander patterns.

RESULTS

Upstream Reach Channel Morphology

The two reaches evaluated for this project represent two different slope conditions within the South Creek stream channel. The following section describes the channel morphology of each upstream reach.

Longitudinal Profile

The longitudinal surveys show that UR-A is steeper, has shorter riffle/pool spacing, and has slightly shallower pool depths than UR-B. The longitudinal profile for UR-A has an average riffle spacing of 81.5 ft, average residual pool depth of 0.7 ft, and riffle to riffle slopes of 0.0059 ft/ft (Tables 3 and Figures 5 and 6). The longitudinal profile for UR-B has an average riffle spacing of 109.5 ft, average residual pool depth of 0.76 ft, and riffle to riffle slopes of 0.0029 ft/ft. The channel is bedrock-controlled in a few places and has very low sinuosity (<1.05) due to channelization. This section of stream has a consistent baseflow as the stream heads just upstream of UR-A at National Avenue.

Channel Dimensions and Flow Capacity

Since the 12,000 ft of the South Creek channel in this study has been channelized, a clearly defined "bankfull" channel was difficult to identify using typical field-based indicators. The general cross-sectional area of the channel is trapezoidal and a small incised low flow channel is forming in the bottom. This "low flow" channel appears to be erosional and is too small for the size of the drainage area to be considered the "bankfull" channel. Further down-cutting and widening of the channel is likely controlled by near surface bedrock and a thick growth of brush and trees help protect the banks from erosion. Furthermore, due to the amount of upstream urbanization, enough fine-grain sediment is likely not being transported to this reach to allow the stream to rebuild a floodplain.

The low flow channel in UR-A is larger than the low flow channel in UR-B that is <3,000 ft downstream. The average low flow channel dimensions for UR-A is 12.5 ft wide, has a mean depth of 0.72 ft, a maximum depth of 1.1 ft, a cross-sectional area of 9.0 ft^2, and a discharge of 26.6 ft^3/s (Table 4). The average low flow channel dimensions for UR-B is smaller than Reach A with a width of 8.2 ft, mean depth of 0.57 ft, maximum depth of 0.9 ft, cross-sectional area of 6.9 ft^2, and a discharge of 11 ft^3/s.

The total channel in UR-B is wider and shallower than the total channel dimensions in UR-A. In UR-A the average total channel width is 59.3 ft, mean depth is 2.9 ft, the maximum depth is 5.1 ft, the total channel cross-sectional area is 176 ft^2, and the total channel discharge is 469 ft^3/s (Table 5). In UR-B the average total channel width is 74.3 ft, mean depth is 2.2 ft, the maximum depth is 3.7 ft, the total channel cross-sectional area is 165 ft^2, and the total channel discharge is 343 ft^3/s.

While the channels within the reference reaches are not typical of natural channels in the area, they appear to be stable over the last decade. In 2004, longitudinal and cross-sectional surveys were conducted in UR-A and UR-B. Comparing the cross-sections shows that the channel has changed very little in 10 years (Figures 7 and 8). This suggests the channel is in equilibrium with the flood regime and sediment supply from the watershed.

<u>Channel Substrate and Sediment Transport</u>
The typical bed substrate was more coarse in UR-B than in UR-A. The average median (D50) bed particle diameter in UR-A was 25 mm and in UR-B it was 49 mm (Table 6). The average D84 was 80 mm in UR-A and 97 mm in UR-B. The average maximum particle size collected during the survey was 123 mm at UR-A and 170 mm in UR-B. In UR-A and UR-B, bedrock is exposed on <10% of the channel bed. Sediment mobility analysis indicates that UR-A can transport larger material than UR-B, but predicted mobile critical bed material diameters exceed the median size on the bed and the upper mobility limit equals or exceeds the field measured D84 in both reaches.

Historical Aerial Photo Analysis

Historical aerial photo analysis indicates the South Creek channel in the project reach has been channelized for a long period of time, even when the watershed was undeveloped. By 1953, the channel between Campbell Avenue and present day Kansas Expressway appears to be channelized sometime prior to the photograph (Figure 9). Upstream of Campbell Avenue in the reference reach the channel appears to be more natural in 1953 showing channel and valley meanders, but well outside the present day channel alignment.

Pre-channelization meanderbelt widths were collected on the five largest meanders along the stream at three locations in the 1953 aerial photo. This shows the meanderbelt width decreases downstream in the pre-disturbed channel. From National to Jefferson the meanderbelt width was 71.3 ft, 48.3 ft from Jefferson to Campbell, and 40.9 ft from Campbell to Kansas Expressway. Present day channel bottom widths are roughly 40-50 ft wide and are too confined to contain meanderbelt widths in the 50-70 ft range.

The 1975 aerial photograph shows significantly more development and that more channelization occurred since 1953. Between 1953 and 1975, the South Creek watershed transformed from being rural to predominantly urban, particularly in the upper portions of the drainage basin (Figure 10). Downstream of Campbell, the channel was moved and straightened into a position similar to the channel location today. Upstream of Campbell the stream was channelized from about station 8,000 ft upstream through what was a more natural channel.

Urban Channel Morphology in Springfield

Since the stream above Campbell has been channelized and doesn't have apparent bankfull indicators in its current state, a set of regional curves for urban stream channels in Springfield are used here to provide information on "typical" urban stream morphology for the area. Figures 11-14 show the relationships between drainage area and bankfull channel dimensions, bedform patterns, and channel planform from these datasets. Using these curves the following information was calculated based on a drainage area of 2.5 mi^2, roughly in the center of the project reach.

<u>Bankfull Channel Dimensions</u>
Width = 19 ft
Max depth = 1.6 ft
Cross-sectional area = 16.5 ft^2
Mean depth = 0.9 ft

<u>Bedform Spacing and Depth</u>
Riffle-riffle spacing = 65 ft
Riffle-pool spacing = 34 ft
Residual pool depth = 0.6 ft

<u>Planform</u>
Meanderbelt width = 40 ft
Meander length (trough-trough) = 183 ft

Comparing the low flow channel to the bankfull channel from the urban regional curves shows South Creek's low flow channel is more narrow, shallower, with longer distance between pools and riffles than the typical urban stream in Springfield. Typical bankfull channel dimensions for other urban streams are 6.5 ft wider and 0.5 ft deeper than the low flow channel in the upstream reach. Riffle-riffle and riffle-pool spacing is 30 ft longer in South Creek compared to other urban channels. The predicted meanderbelt width is similar to the lowest measured meanderbelt width from the 1953 aerials suggesting that 40 ft is a fairly good estimate.

CONCLUSIONS

This report provides geomorphic information necessary to support channel restoration efforts in the upper South Creek watershed in Springfield, Missouri. This includes present channel conditions upstream of the project reach, historical information on the channel from aerial photographs, and what the typical channel would be in an urban stream in the area. There are six main conclusions from this study:

1. **Long-term continuous flow gaging at Campbell Avenue shows the stream has relatively consistent flow throughout the year.** The 90% exceedance flow at Campbell Avenue is 0.04 ft^3/s, the 50% flow exceedance discharge is 0.24 ft^3/s and the 10% exceedance flow is 0.59 ft^3/s. The maximum flow recorded over the last two years is 675 ft^3/s. The stream was dry for about 2% of the year, during a very dry hot summer.

2. **The upstream reaches evaluated for this project do not display the typical bankfull morphology that is likely due to channelization and lack of fine-grain material in the upper watershed.** For this study, a clearly defined "bankfull" channel was difficult to identify using typical field-based indicators. The general cross-sectional area of the channel is trapezoidal and a small incised low flow channel is forming in the bottom. Furthermore, due to the amount of upstream urbanization, enough fine-grain sediment is likely not being transported to this reach to allow the stream to rebuild a floodplain.

3. **While the channel through the upstream reach has been channelized for some time, it has been very stable over the last decade.** While the channel in the upstream reach are not typical of natural channels in the area, the channel does appear to be stable over the last decade. Comparing the cross-sections from this study to a 2004 survey shows that the channel has changed very little in 10 years. This suggests the channel is in equilibrium with the flood regime and sediment supply from the watershed.

4. **Historical aerial photo analysis shows the channel has a long history of human disturbance including several periods of channelization since 1953.** Portions of The channel between Campbell Avenue and present day Kansas Expressway appears to be channelized sometime prior to 1953. Upstream of Campbell Avenue in the upstream reach the channel appears to be more natural in 1953 showing channel and valley meanders well outside the present day channel alignment. The 1975 aerial photograph shows significantly more development and that more channelization occurred since 1953.

5. **The typical channel morphology of a stream with a drainage area of this size would be expected to be larger than the low-flow channel in the upstream reach.** Since the stream above Campbell has been channelized and doesn't have apparent bankfull indicators

in its current state, a set of regional curves for urban stream channels in Springfield are used here to provide information on "typical" urban stream morphology for the area. The typical urban channel is expected to be significantly larger than the present low flow channel in the upstream reach.

6. **Sediment transport appears to be limited due to low sediment loads and lack of fine-grain from upstream.** The bed within the upstream reach is a mixture of gravel with some cobble and occasional bedrock suggesting the stream has a limited ability to downcut. The stable morphology, lack of bars, and lack of fine-grained bank deposits suggests that sediment loads are relatively low, but exact rates are not known yet. Thus, resistant beds, low bed sediment deposition rates, and lack of fines allow the channel to maintain a stable form but will reduce channel recovery due to new channel disturbances.

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Rosgen, D., 2006. <u>Watershed Assessment of River Stability and Sediment Supply (WARSSS).</u> Wildland Hydrology, Fort Collins, Colorado.

Simon, A and M. Rinaldi, 2000. Channel Instability in the Loess Area of the Midwestern United States. Journal of the American Water Resources Association 36(1):133-150.

TABLES

Table 1. Flow Exceedance from January 2012 - June 2014

Flow Exceedance %	Discharge (ft^3/s)
Minimum	0.0
90%	0.04
50%	0.24
10%	0.59
Maximum	675

Table 2. Source Information for Aerial Photography

Photo Date	Originator	Source
09-20-1953	U.S. Department of Agriculture. Soil Conservation Service. Aerial Photography Field Office	MSU Library
01-23-1975	U.S. Geological Survey, National Aerial Photography Program	EarthExplorer
02-19-2009	City of Springfield	City of Springfield

Table 3. Upstream Reach Bedform Morphology

Reach	Riffle-Riffle Slope (ft/ft)	Riffle Spacing (ft)	Pool Spacing (ft)	Riffle - Pool Spacing (ft)	Max Residual Pool Depth (ft)
Reach A	0.0059	81.5	80.5	61.0	0.70
Reach B	0.0029	109.5	107.9	59.1	0.76
Average	0.0044	95.5	94.2	60.0	0.73

Table 4. Upstream Reach Low Flow Channel Morphology

X-Section	Width	Max Depth	Mean Depth	Area	Slope	Hydraulic Radius	Velocity (n=0.028)	Q
	ft	ft	ft	ft^2	ft/ft	ft	ft/s	ft^3/s
Reach A								
Sec. 1	12.3	1.4	0.80	9.82	0.0049	0.77	3.1	30.8
Sec. 2	11.6	0.9	0.67	7.71	0.0049	0.64	2.8	21.4
Sec 3	13.7	1.1	0.70	9.60	0.0049	0.68	2.9	27.6
Reach Mean	12.5	1.1	0.72	9.04	0.0049	0.70	2.9	26.6
Reach B								
Sec 1	6.7	0.9	0.63	4.21	0.0044	0.59	2.5	10.4
Sec 2	6.8	1.0	0.65	4.41	0.0044	0.57	2.5	10.8
Sec 3	10.9	0.9	0.50	5.42	0.0044	0.48	2.2	11.8
Reach Mean	8.2	0.9	0.57	4.68	0.0044	0.55	2.4	11.0
Mean (n=6)	10.3	1.0	0.66	6.86	0.0047	0.62	2.7	18.8

Table 5. Upstream Reach Total Channel Cross-Section Morphology

X-Section	Width	Max Depth	Mean Depth	Area	Slope	Hydraulic Radius	Velocity (n=0.08)	Q
	ft	ft	ft	ft^2	ft/ft	ft	ft/s	ft^3/s
Reach A								
Sec. 1	48.7	4.3	2.22	108	0.0049	2.17	2.2	235
Sec. 2	62.4	5.1	3.02	188	0.0049	2.94	2.7	500
Sec 3	66.9	5.9	3.47	232	0.0049	3.36	2.9	673
Reach Mean	59.3	5.1	2.90	176	0.0049	2.82	2.6	469
Reach B								
Sec 1	72.5	4.2	2.57	186	0.0044	2.52	2.3	423
Sec 2	73.4	3.6	2.06	151	0.0044	2.02	2.0	296
Sec 3	77.0	3.4	2.04	157	0.0044	2.02	2.0	308
Reach Mean	74.3	3.7	2.22	165	0.0044	2.18	2.1	343
Mean (n=6)	66.8	4.4	2.56	170	0.0047	2.50	2.3	406

Table 6. Upstream Reach Sediment Transport at Total Channel Stage

X-Section	Slope ft/ft	Hydraulic Radius	Mean Boundary Shear Stress (lb/ft)	Critical Dia 1 (mm)	Critical Dia 2 (mm)	D50 (mm)	D84 (mm)	Dmax (mm)
Reach A								
Sec. 1	0.0049	2.17	0.66	51	112	15	110	170
Sec. 2	0.0049	2.94	0.90	70	141	20	60	90
Sec 3.	0.0049	3.36	1.03	80	155	40	70	110
Mean (n=3)	0.0049	2.82	0.86	67	136	25	80	123
Reach B								
Sec. 1	0.0044	2.52	0.69	53	116	70	120	200
Sec. 2	0.0044	2.02	0.55	42	99	33	84	120
Sec. 3	0.0044	2.02	0.55	42	99	45	87	190
Mean (n=3)	0.0044	2.19	0.60	46	104	49	97	170

FIGURES

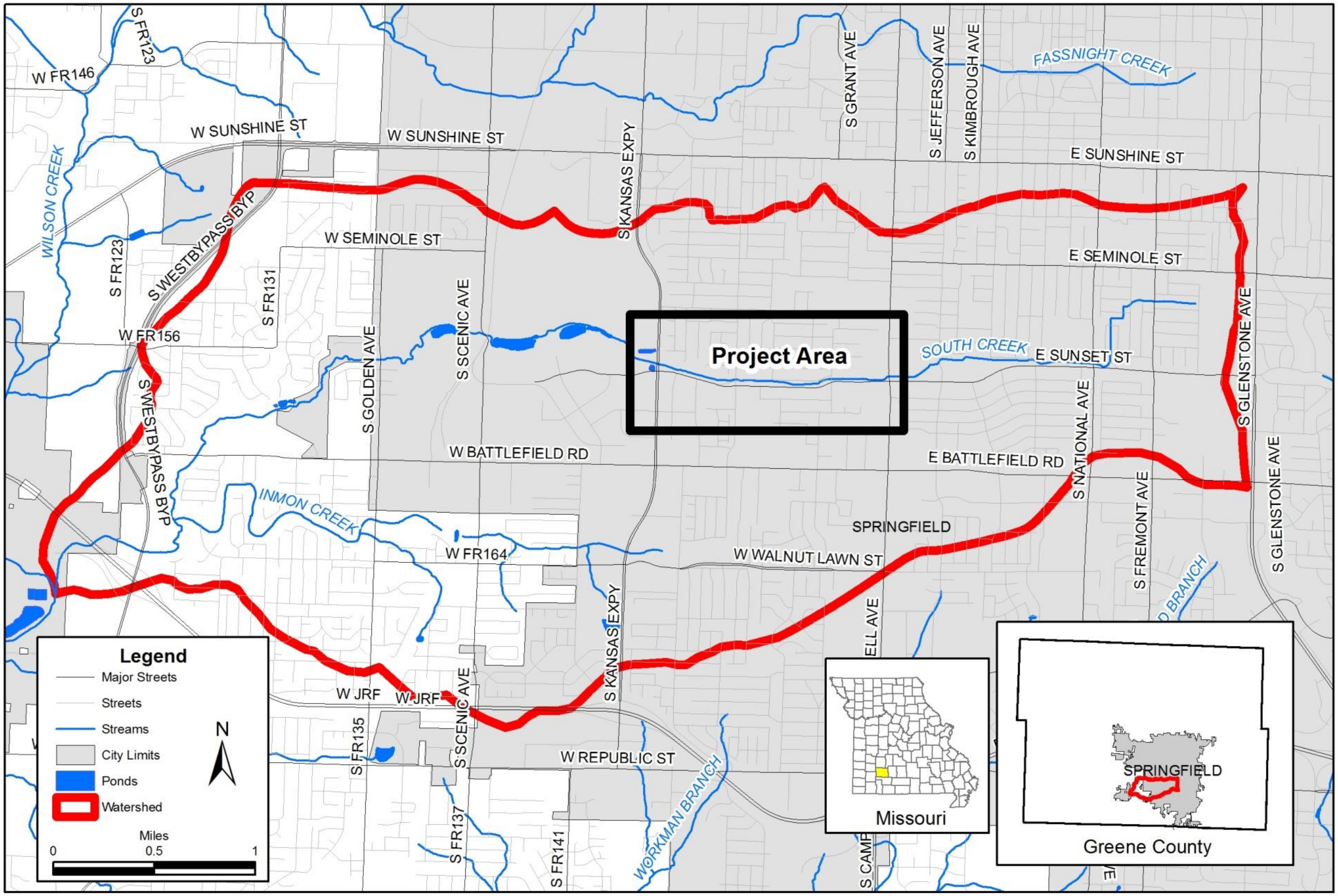


Figure 1. South Creek watershed and project area

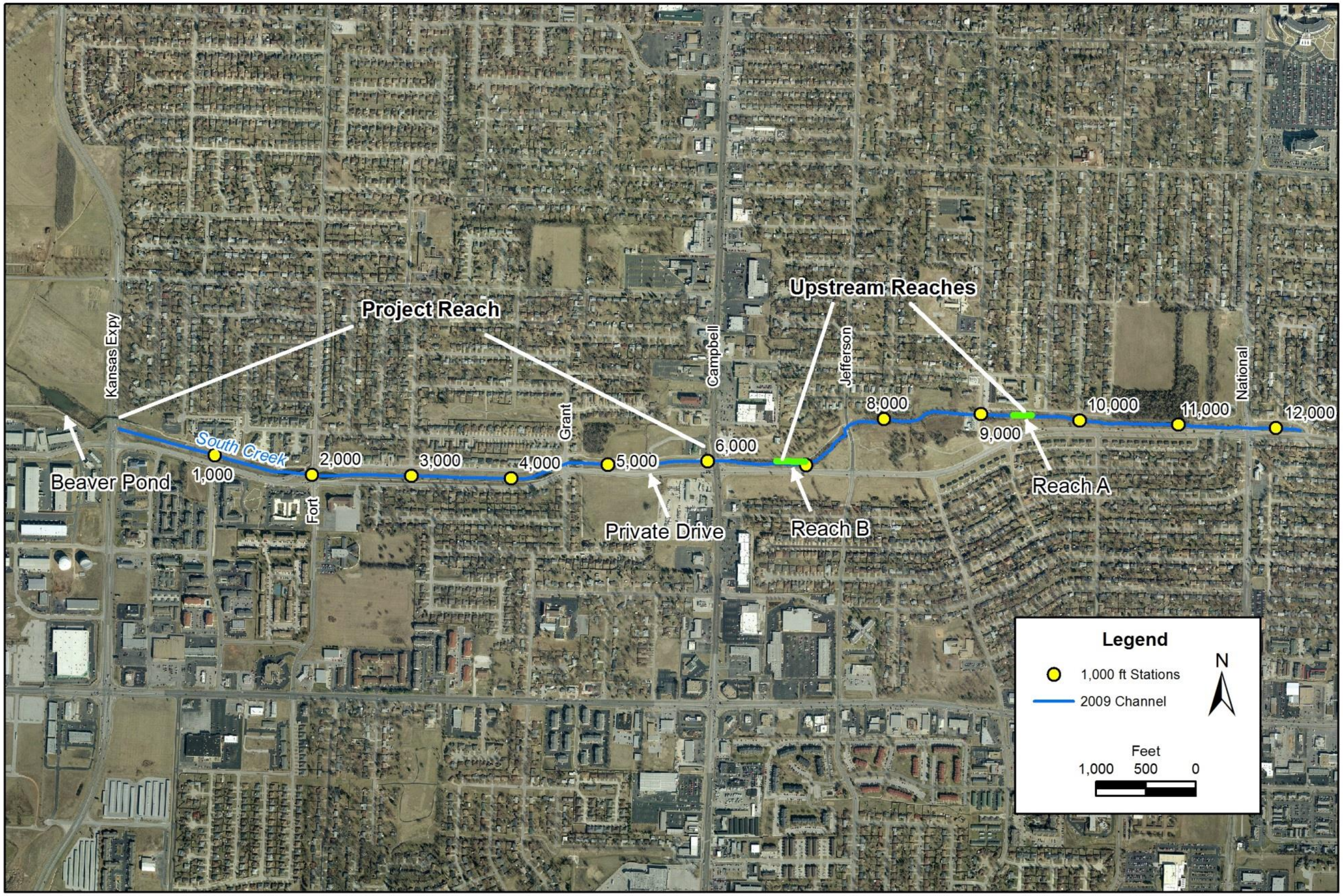


Figure 2. The project reach and upstream reach locations.

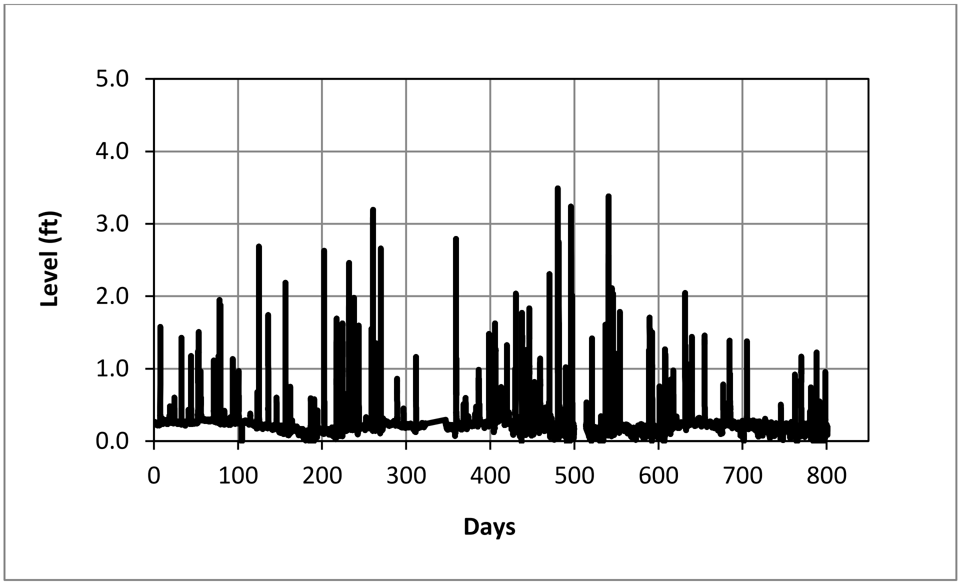


Figure 3. Stage records at Campbell Avenue from January 2012 to June 2014.

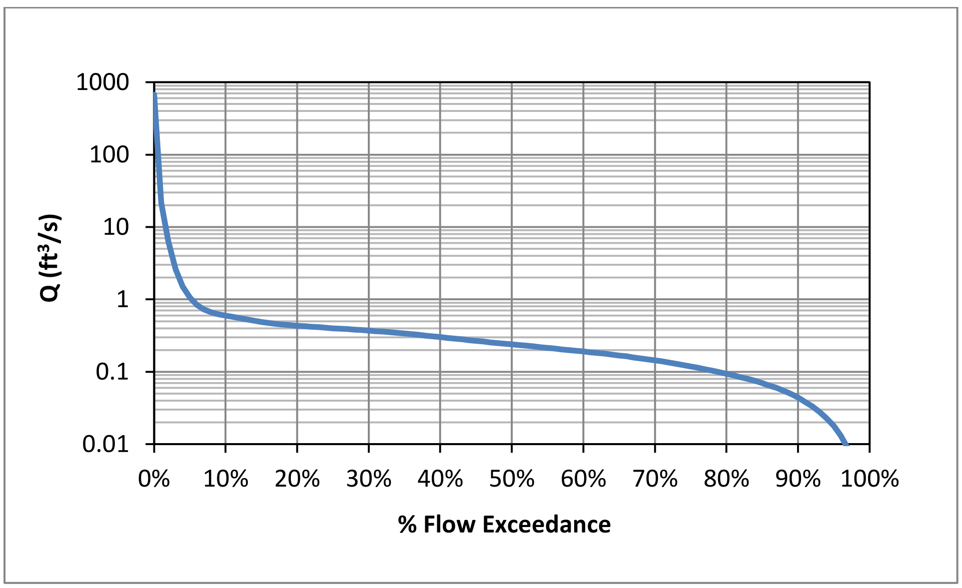


Figure 4. Flow duration curve for Campbell Avenue from January 2012-June 2014.

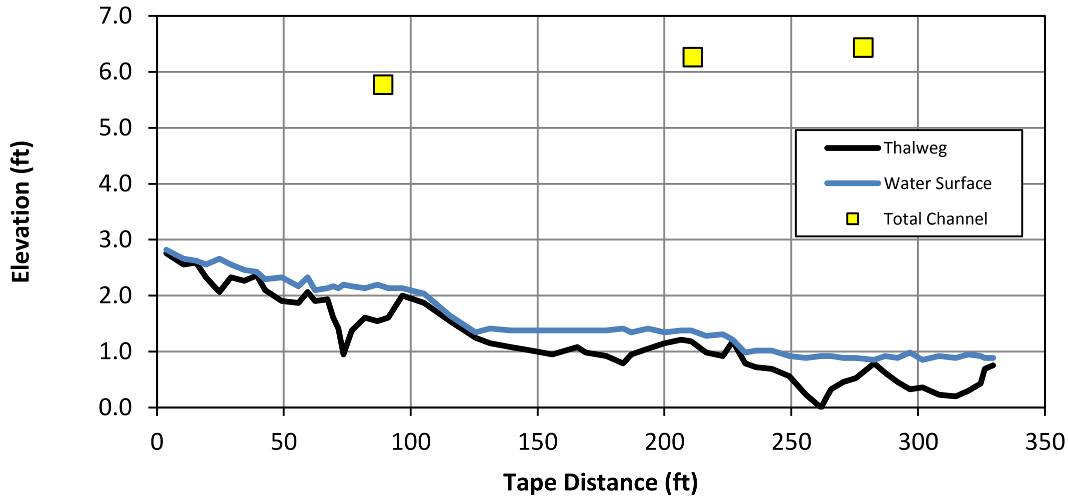


Figure 5. Longitudinal profile of upstream reach A

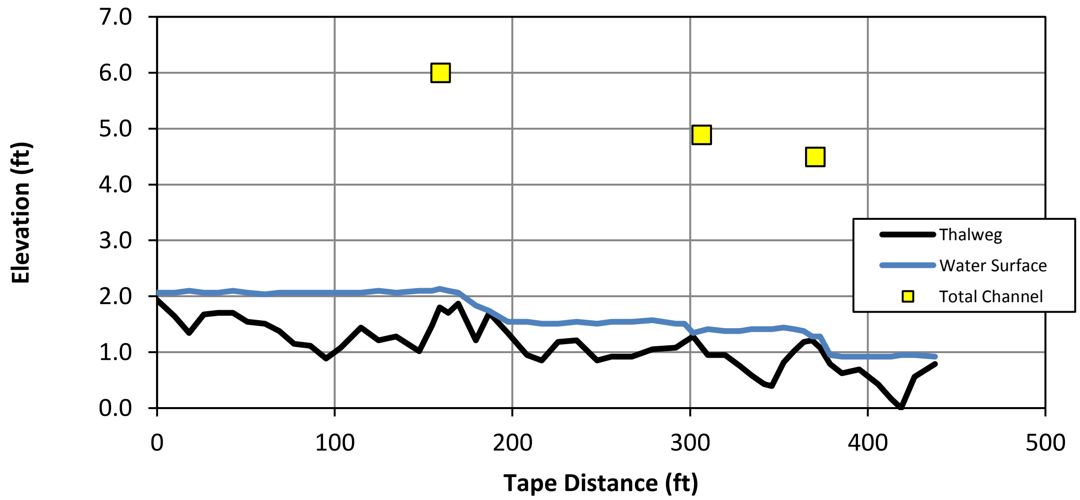
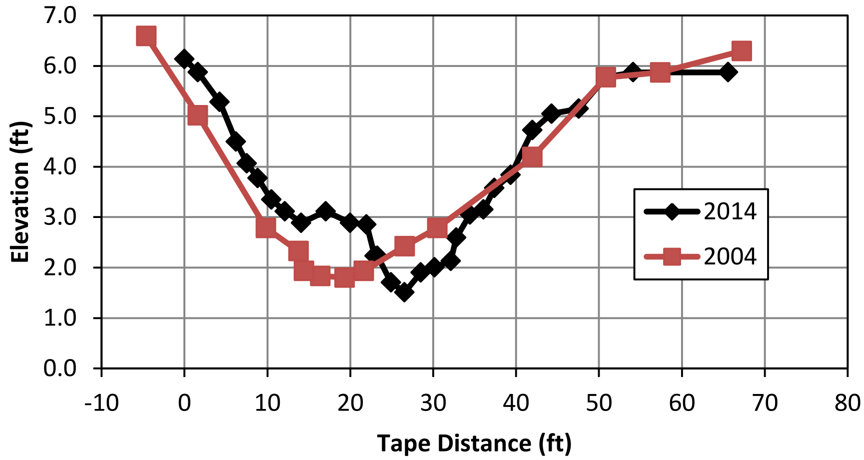
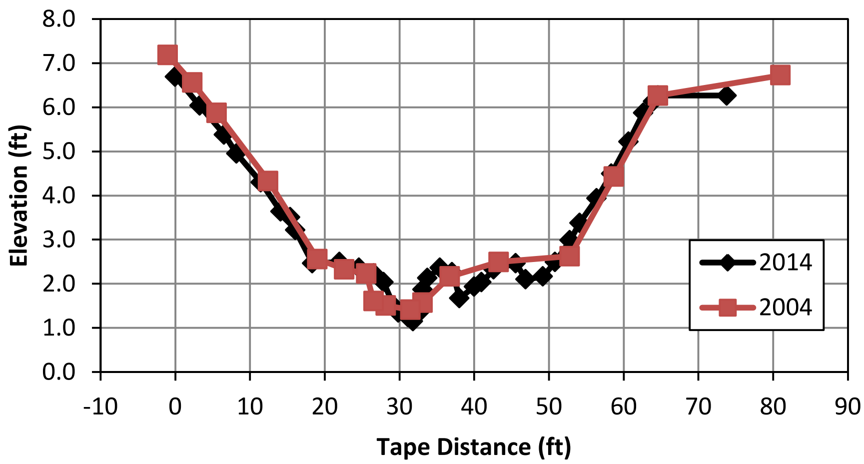


Figure 6. Longitudinal profile from upstream reach B





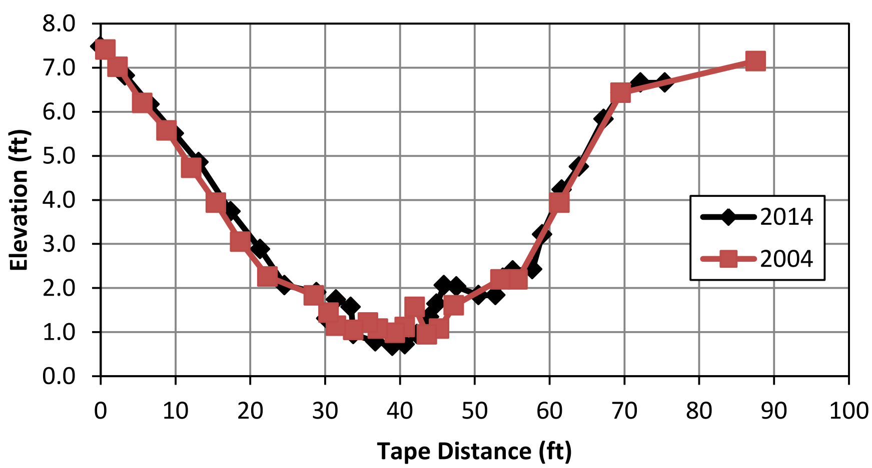


Figure 7. Change in upstream reach A cross-section from 2004-2014

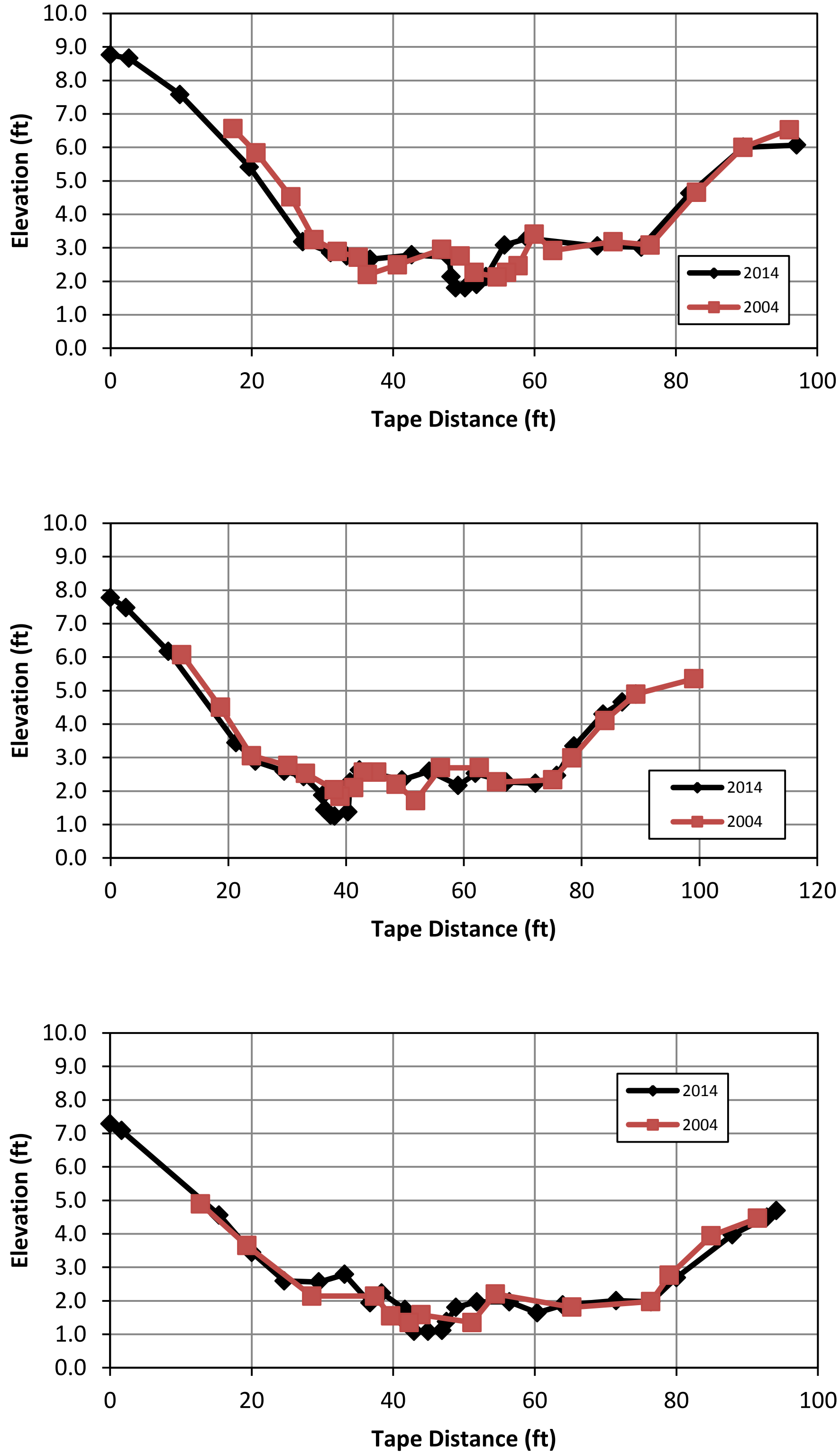


Figure 8. Change in upstream reach B cross-section from 2004-2014

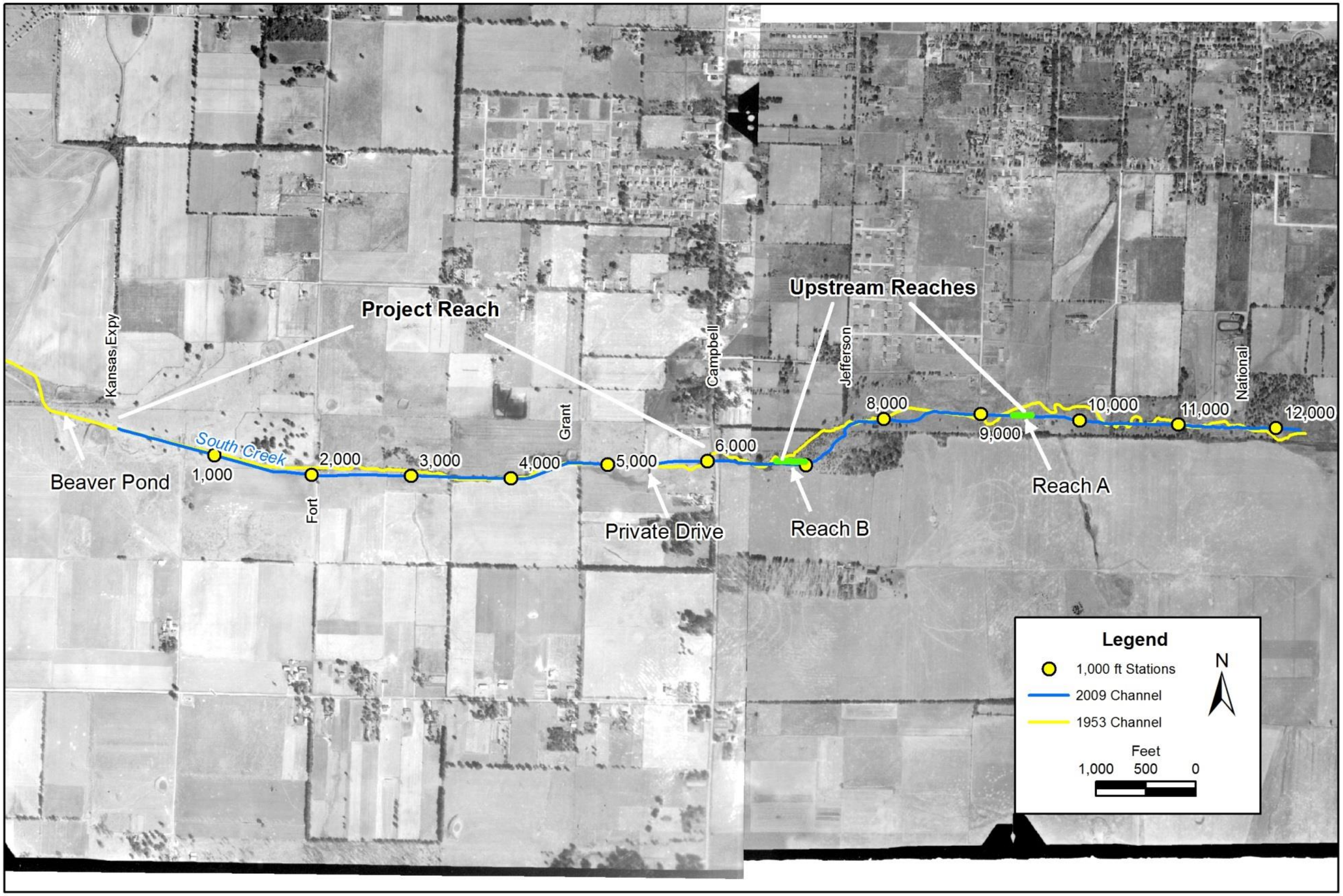


Figure 9. 1953 aerial of the project reach and upstream reaches.

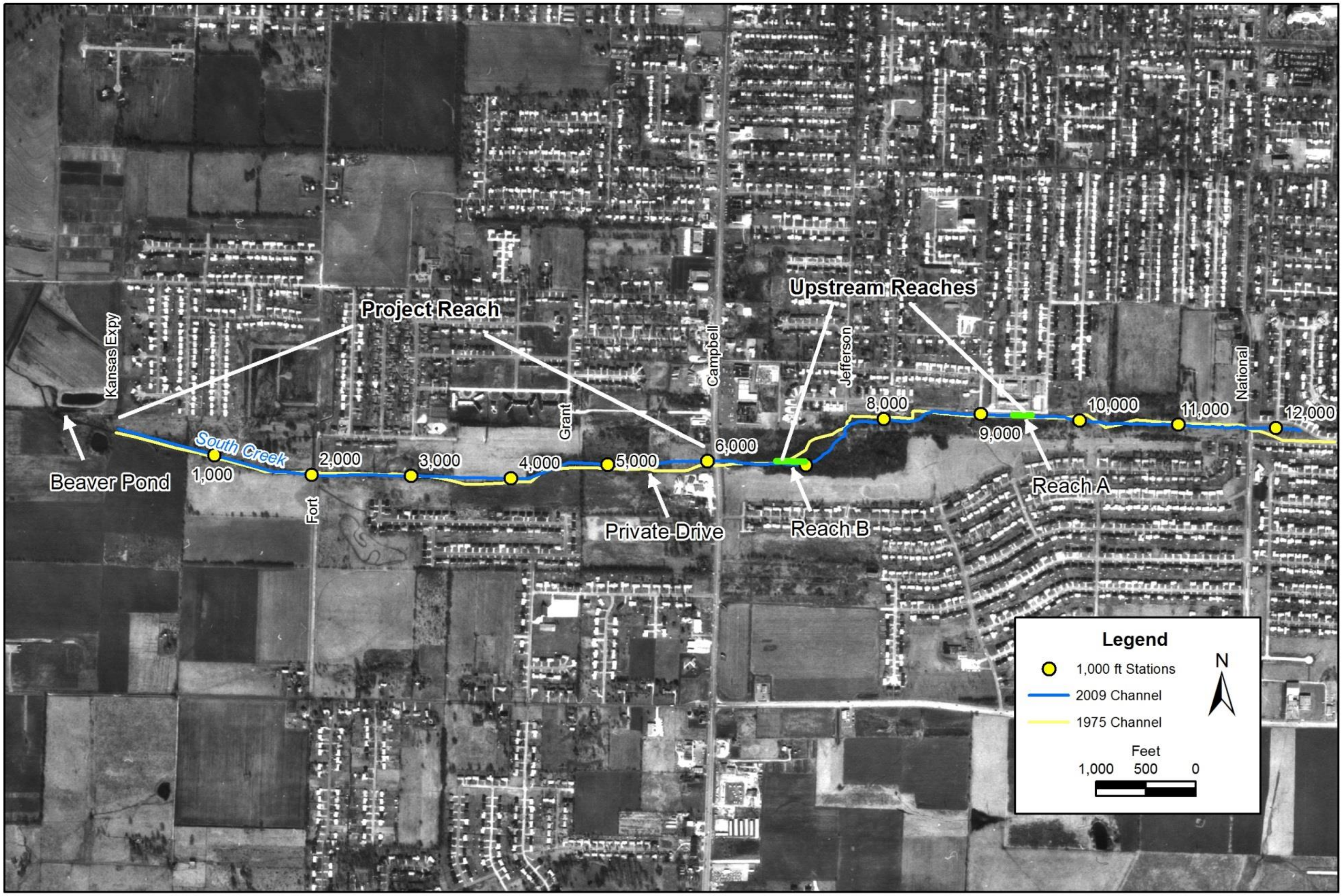


Figure 10. 1975 aerial of project and upstream reaches.

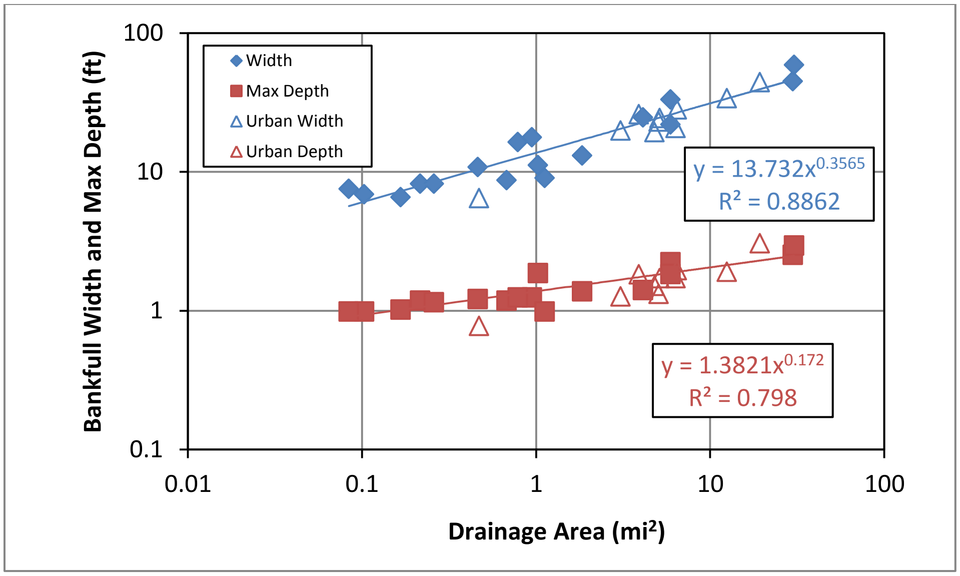


Figure 11. Springfield urban stream regional curves for bankfull width and max depth.

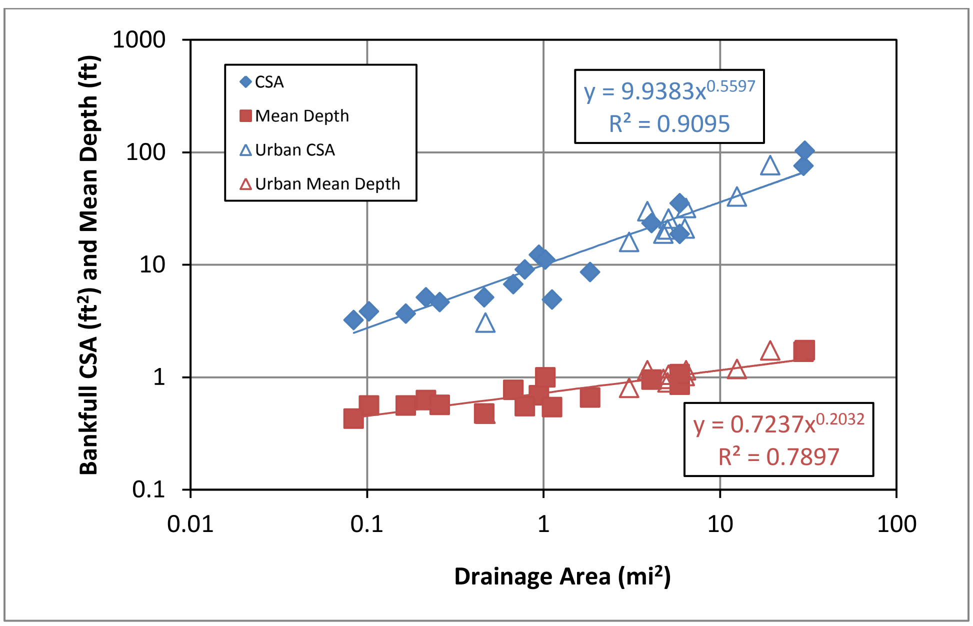


Figure 12. Springfield urban stream regional curves for bankfull cross-sectional area and mean depth.

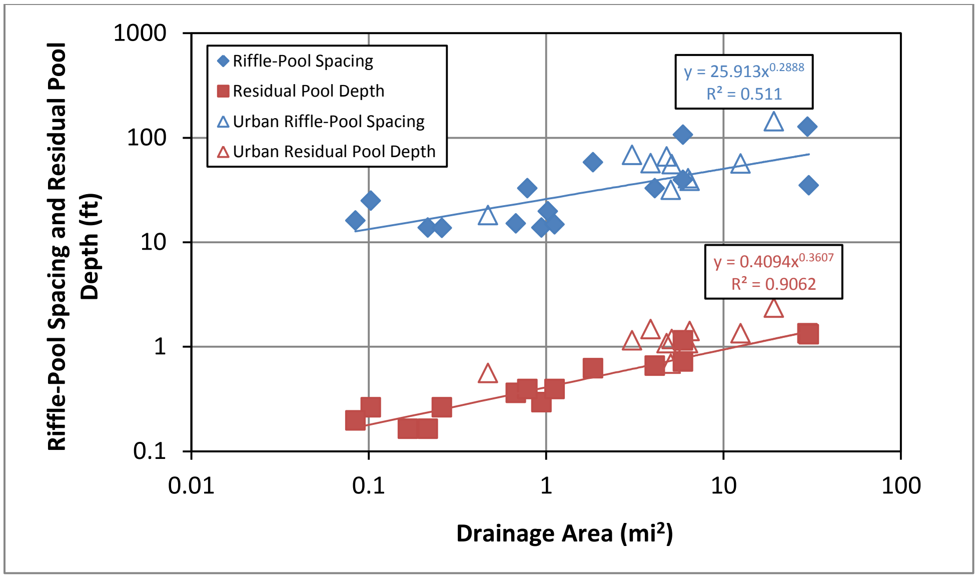


Figure 13. Springfield urban stream regional curves for riffle-pool spacing and max residual pool depth.

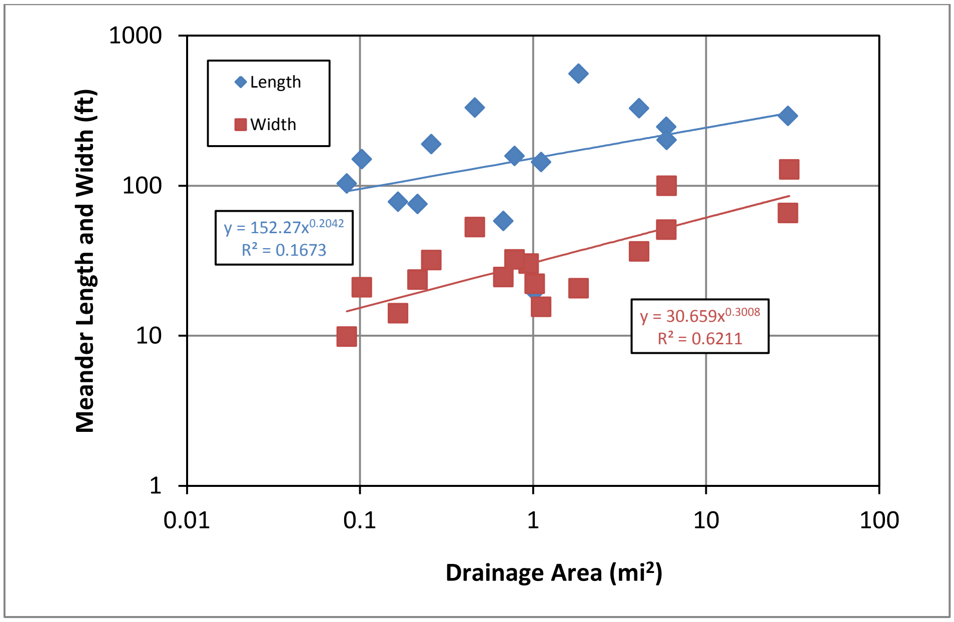


Figure 14. Springfield urban stream regional curves for meander length and meanderbelt width.

PHOTOS

Photo 1. Reach A, cross-section 1, looking downstream (7-9-14)

Photo 2. Reach A, cross-section 1, looking upstream (7-9-14)


Photo 3. Reach A, cross-section 2, looking downstream (7-9-14)


Photo 4. Reach A, cross-section 2, looking upstream (7-9-14)


Photo 5. Reach A, cross-section 3, looking downstream (7-9-14)


Photo 6. Reach A, cross-section 3, looking upstream (7-9-14)


Photo 7. Reach B, cross-section 1, looking downstream (7-9-14)


Photo 8. Reach B, cross-section 1, looking upstream (7-9-14)

Photo 9. Reach B, cross-section 2, looking downstream (7-9-14)

Photo 10. Reach B, cross-section 2, looking upstream (7-9-14)

Photo 11. Reach B, cross-section 3, looking downstream (7-9-14)


Photo 12. Reach B, cross-section 3, looking upstream (7-9-14)